Empirical Correction To Tropical Heating:

Can We Correct Mid-Latitude Model Biases?

David M. Straus
George Mason University / COLA

Youkyoung Jang
Florida International University

J. Shukla
George Mason University / COLA

Goals of This Research

Apply a technique to reduce the tropical bias in monthy mean diabatic heating in CESM simulations

Verify that some aspect of the mid-latitude bias in stationary waves is reduced

Determine if seasonal forecasts from real Initial Conditions are so improved.

Simple Recipe to Correct Model Tropical Heating Bias

- Zeroth Order "Correction" Technique

  - Subtract model bias in monthly mean climatological tropical diabatic heating
  - Three-dimensional model bias in diabatic heating is estimated from:
    (a) 49 Oct-March simulations with CESM 1.0.5
    (b) Estimates of observed diabatic heating from Chan and Nigam (2009)*
  - The correction term (equal to minus the model bias) *is added directly to the tendency of dry static energy in the coupled model*
  - *The model moist, radiation and other parameterizations are still fully operative,* thus can react to the added heating
  - All the coupled model feedbacks are retained

*Chan, S. C. and S. Nigam, 2009: Residual diagnosis of diabatic heating from ERA-40 and NCEP reanalyses: Intercomparisons with TRMM. *J. Climate*, **22**, 414 - 428.

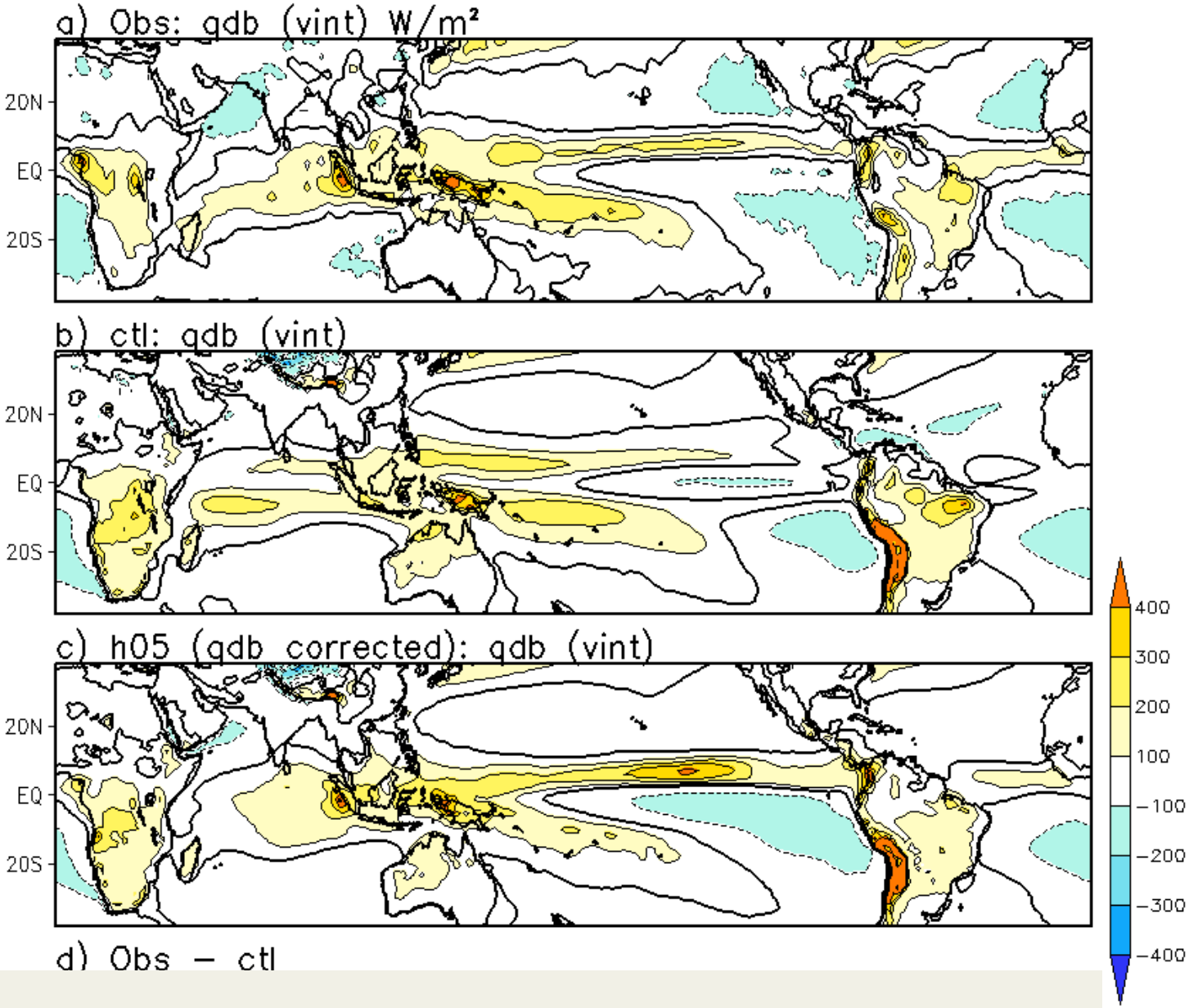
Simple Recipe to Correct Model Tropical Heating Bias

- First Order "Correction" needed:
  - Model heating reacts so as to magnify correction and thereby lead to over-correcting
  - Simple fix is to multiply the heating correction by 0.5

Observed Heating

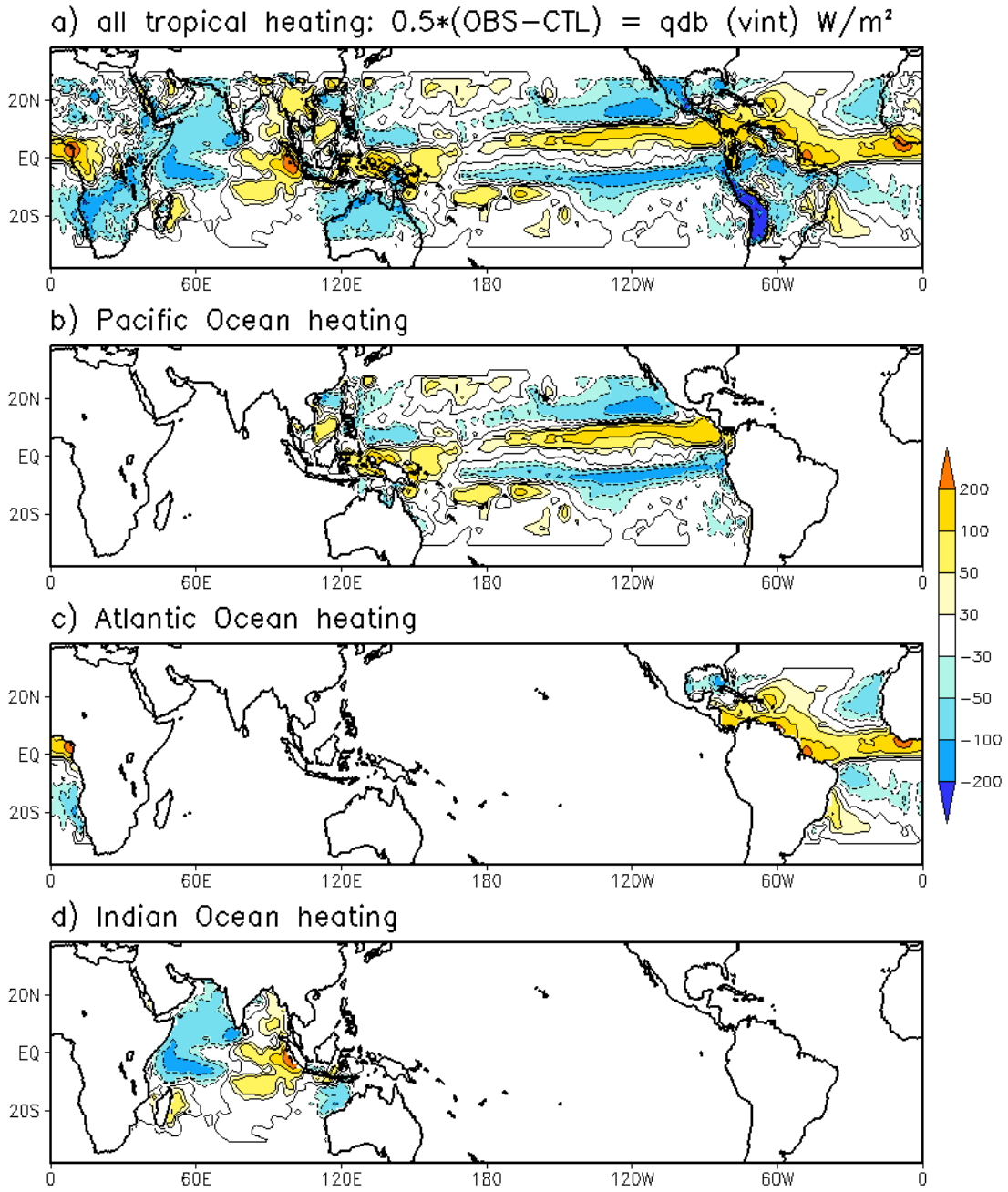
Control CESM Heating

Heating with First Order Correction



Vertically Integrated Heating (Oct-Mar)
(a) Chan-Nigam Obs (b) Control CESM (c) Corrected CESM

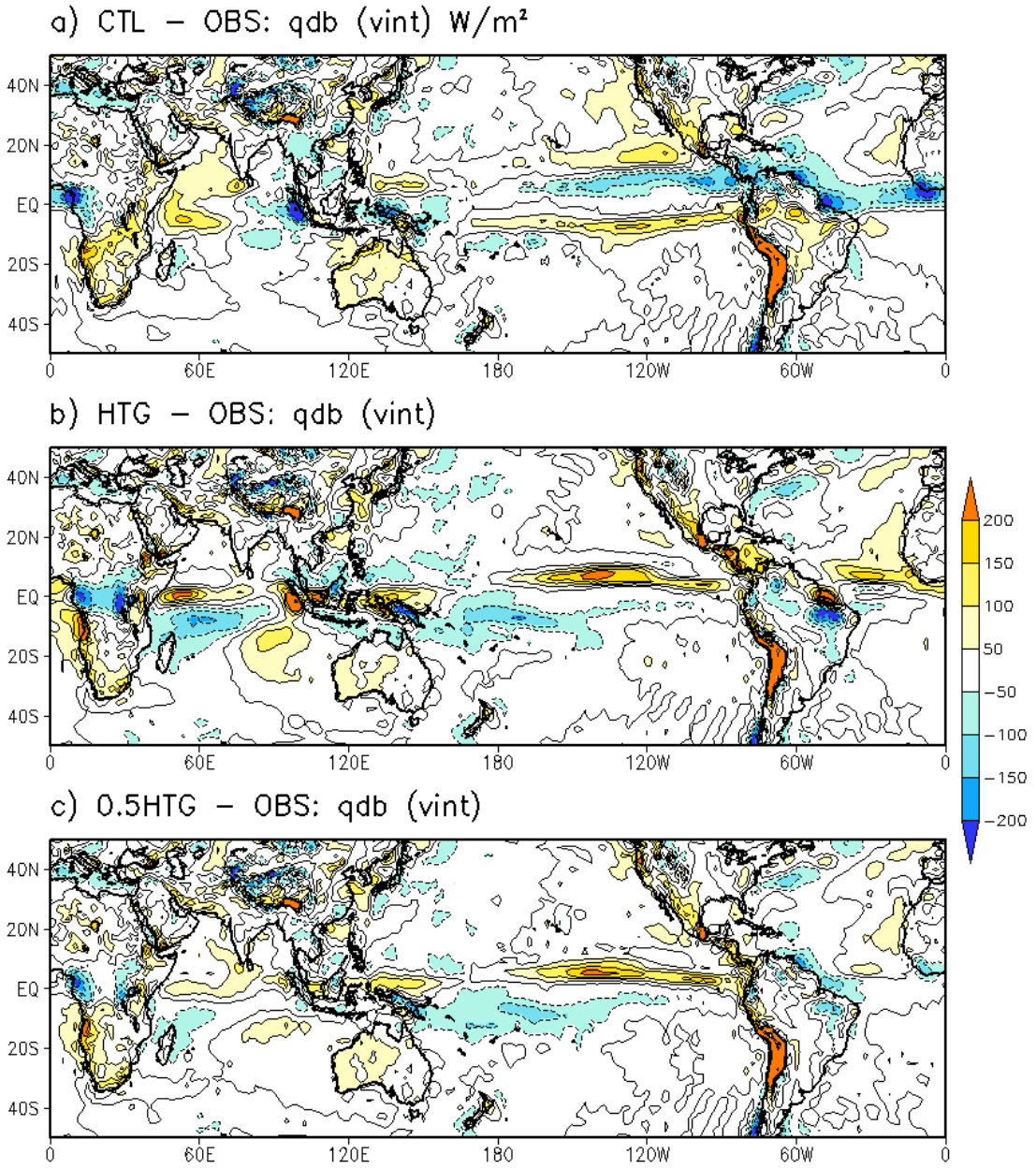
Vertical Integral of the Correction Added to Temperature Tendencies of CESM (Oct-Mar avg)



Control CESM Heating = Q_{GCM}

$dT/dt = \ldots + (Q_{OBS} - Q_{GCM})$
(Zeroth Order Correction)

$dT/dt = \ldots. + 0.5 * (Q_{OBS} - Q_{GCM})$
(First Order Correction)



Oct-Mar Vertically Integrated Heating Biases

Simple Recipe to Correct Model Tropical Heating Bias

- Second Order "Correction" needed:
  - Model heating reacts so as to magnify correction and thereby lead to over-correcting.
  - Simple fix is to multiply the heating correction by 0.5
  - Clearly this is not adequate

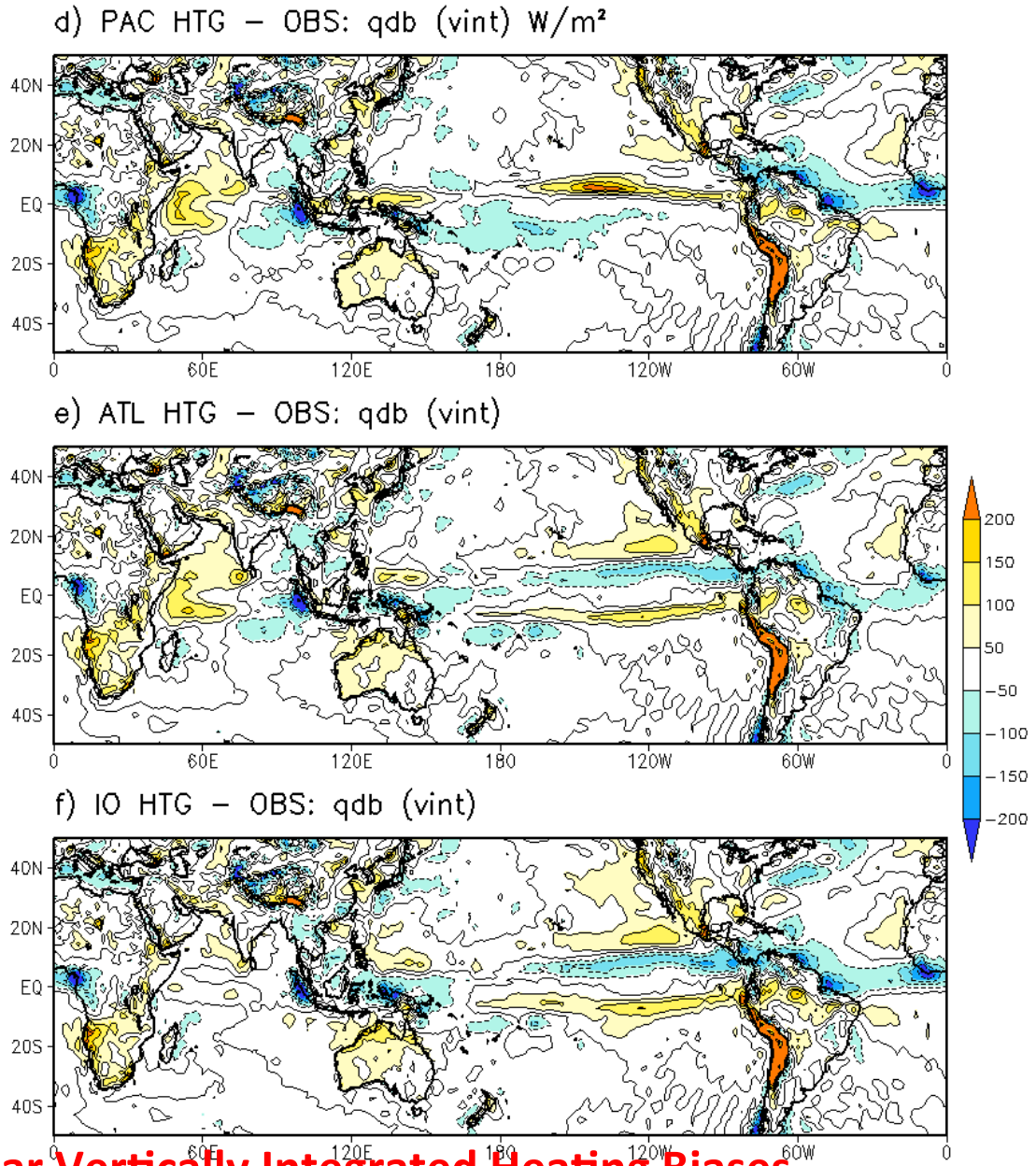
- Higher Order "Correction" will be needed:

  Iterate this technique to provide an additive correction term that will reduce the climatological model tropical diabatic heating error to near zero (on a monthly basis)

Pacific Basin Only

Atlantic Basin Only

Indian Ocean Basin Only



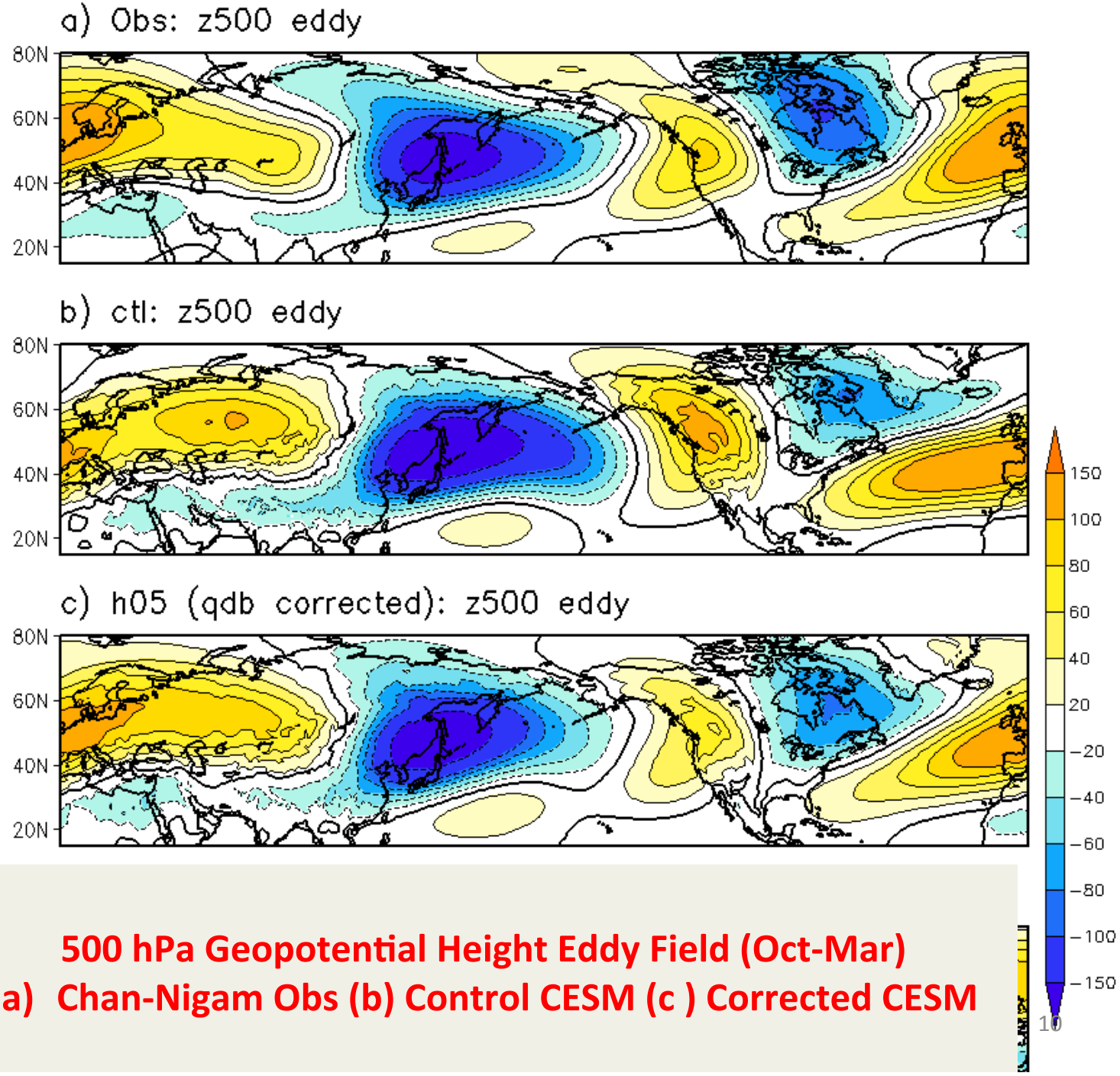
Oct-Mar Vertically Integrated Heating Biases

Regional Heating Correction Experiments

Observed Heating

Control CESM Heating

Heating with First Order Correction

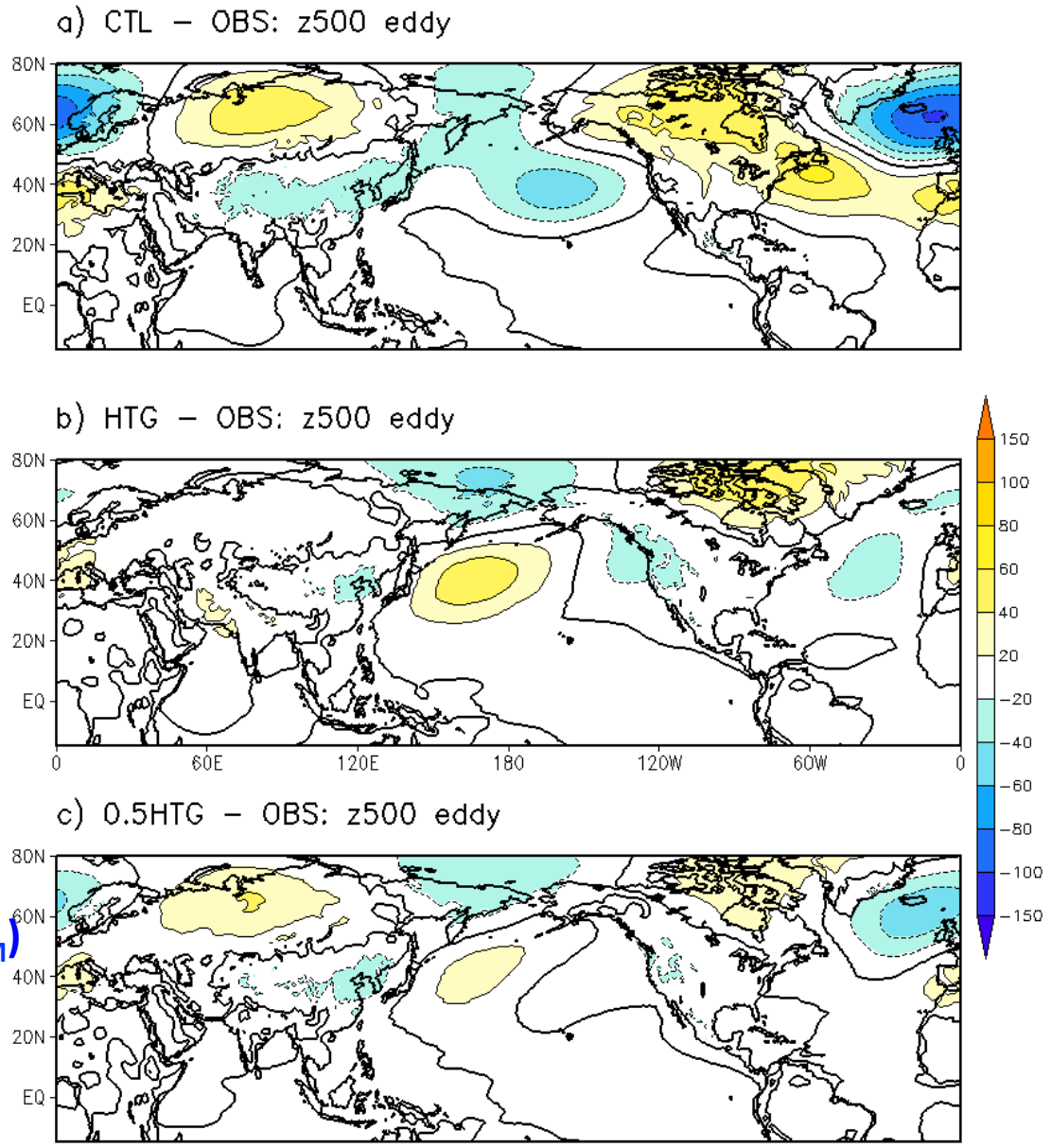


500 hPa Geopotential Height Eddy Field (Oct-Mar)
(a) Chan-Nigam Obs (b) Control CESM (c) Corrected CESM

Control CESM Heating = Q_{GCM}

$dT/dt = \ldots + (Q_{OBS} - Q_{GCM})$
(Zeroth Order Correction)

$dT/dt = \ldots. + 0.5 * (Q_{OBS} - Q_{GCM})$
(First Order Correction)



Bias in 500 hPa Geopotential Eddy Field (Oct-Mar)

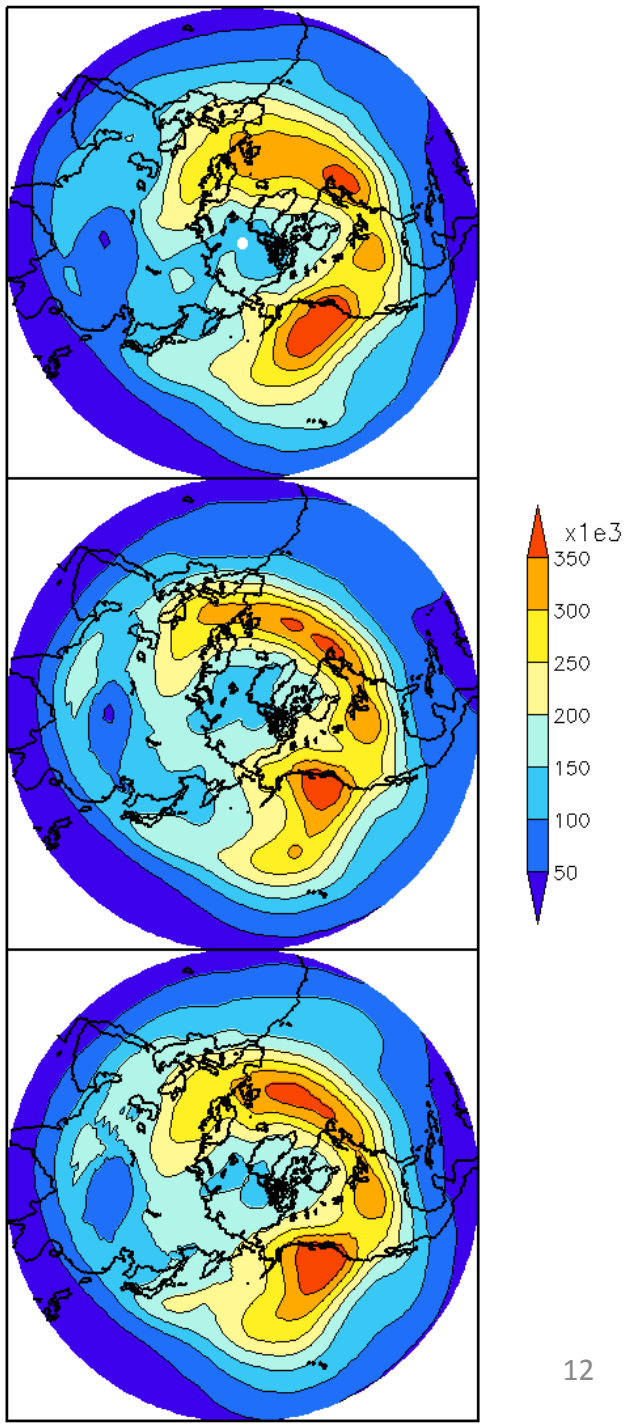
Sub-Monthly Transients
300 hPa meridional velocity

$$\overline{v'v'} = \overline{v^2} - \left(\overline{v}\right)^2$$

a)DJFM vv300: OBS

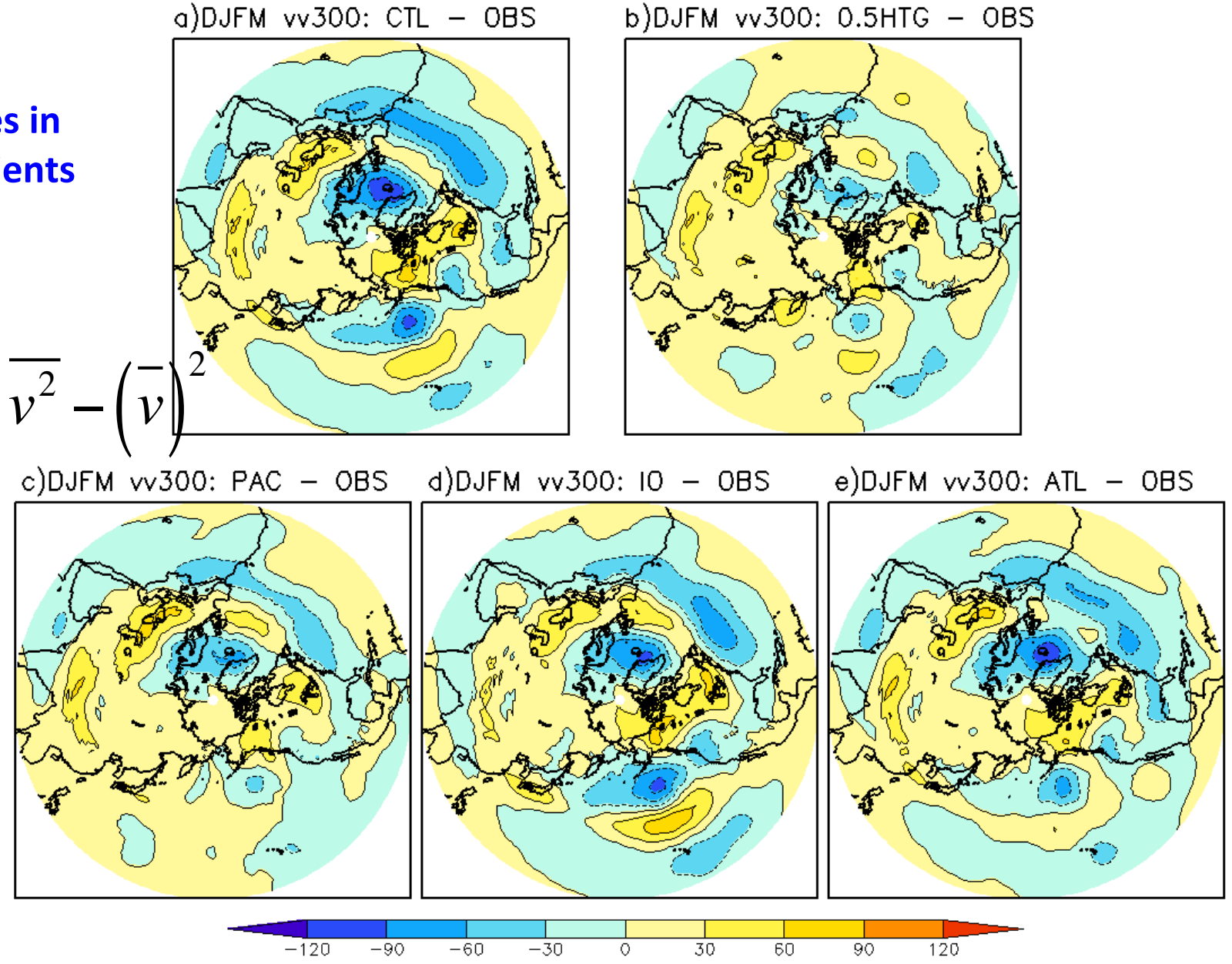
b)DJFM vv300: CTL

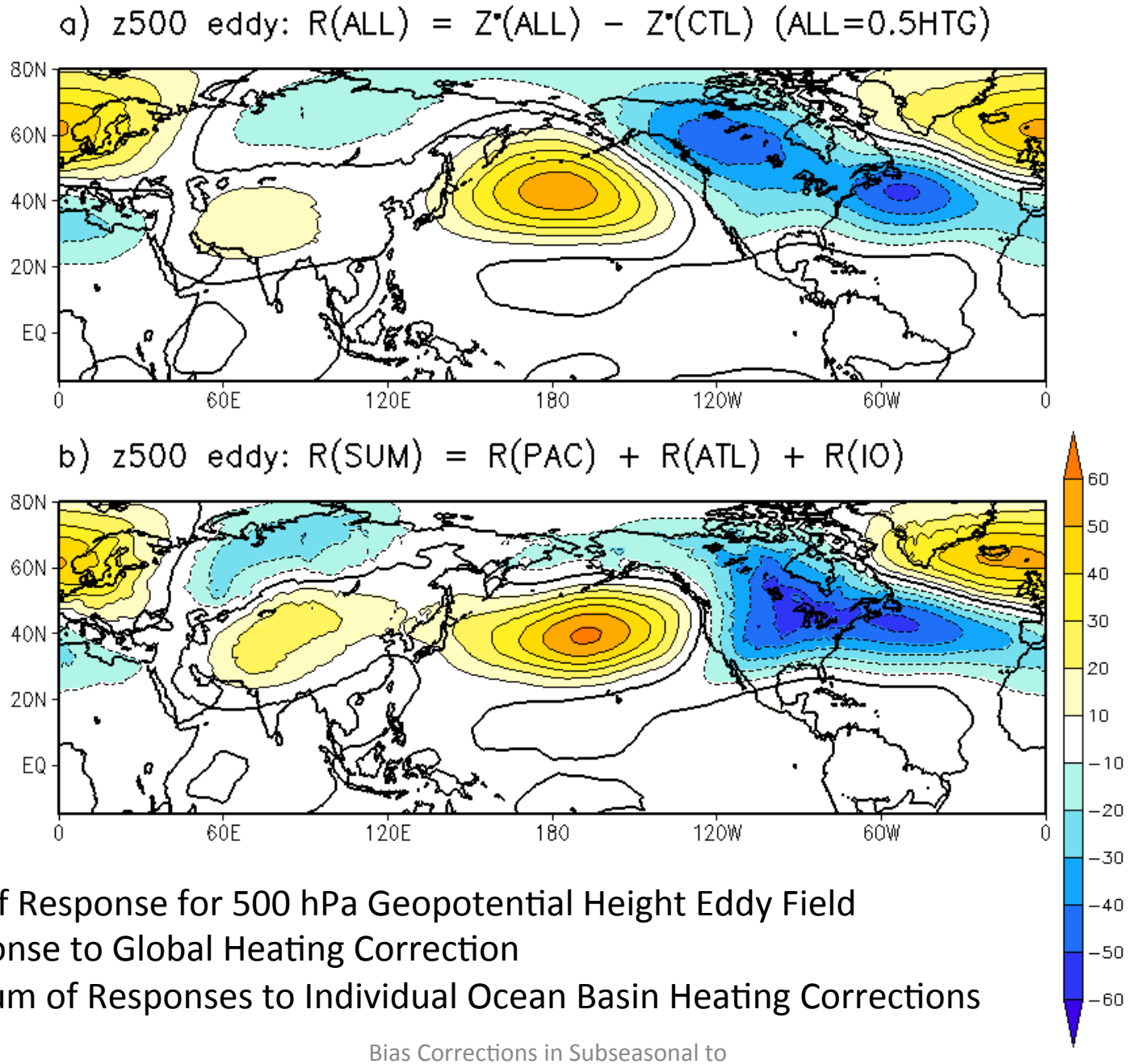
c)DJFM vv300: 0.5HTG



Biases in Transients

$$\overline{v'v'} = \overline{v^2} - \left(\overline{v}\right)^2$$





Linearity of Response for 500 hPa Geopotential Height Eddy Field
Top: Response to Global Heating Correction
Bottom: Sum of Responses to Individual Ocean Basin Heating Corrections

Conclusions

- **Heating correction does reduce heating biases (particularly double ITCZ)**
- **More work needed on refining the heating correction**
- **Stationary Waves in Mid-Latitude Atlantic Region clearly improved**
- **Corresponding improvement is seen in sub-monthly transients**
- **This improvement mostly due to correction of the Pacific Basin Heating**

Future Work

Apply the bias reduction in seasonal re-forecasts:
Will it lead to any improvement in forecast skill?